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# North American Acid Deposition Data Base System (ADS) and Its Use in Spatial Analysis

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# NORTH AMERICAN ACID DEPOSITION DATA BASE SYSTEM (ADS) AND ITS USE IN SPATIAL ANALYSIS

by

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16. ABSTRACT

This presentation describes the Acid Deposition System (ADS). The system is the central database for the different monitoring efforts from several organization in North America collecting acid rain data. The presentation depicts how data from the U.S. and Canada may be used by the acid rain scientific community.

17. KEY WORDS AND DOCUMENT ANALYSIS

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# NORTH AMERICAN ACID DEPOSITION DATA BASE SYSTEM (ADS) AND ITS USE IN SPATIAL ANALYSIS

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The ADS data base contains wet precipitation chemistry data from the APIOS, APN, CANSAP, EPRI/SURE, MAP3S/PCN, NADP and UAPSP networks. Data is stored in a common format yet network specific details are preserved. Primary identification of sites by geographic location facilitates spatial analysis, especially for collocated sites. Hard copy reports summarizing sites, time periods and/or chemical components and data tapes of the information in a uniform format are available. Spatial analysis of combined NADP and CANSAP information for the year July 1980 to June 1981 was performed using a statistical technique called kriging. Contour maps show the lowest annual average pH is slightly less than 4.2 pH units in the north central United States. Precipitation weighted hydrogen ion deposition exceeds 60 milli eq/$m^2$ over Ohio, West Virginia and western Pennsylvania. The north central states and southeastern Canada exceed an annual deposition of 3 g/$m^2$ for sulfate. Nitrate and ammonium depositions exceed 2 g/$m^2$ and 0.4 g/$m^2$, respectively, in southern Ontario and Ohio with much of Indiana and Michigan included for ammonium as well.

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# NORTH AMERICAN ACID DEPOSITION DATA SYSTEM (ADS) AND ITS USE IN SPATIAL ANALYSIS

## Introduction

The Acid Deposition System (ADS) for statistical reporting of acid precipitation data has been established by the U.S. Environmental Protection Agency. The ADS data base system provides an integrated centralized data bank for atmospheric deposition data collected by monitoring networks in North America. The purpose of the centralized data base is (1) to facilitate access to deposition data collected by different organizations (2) to provide annual inventory of available data and (3) to maintain the data for the assessment of long-term national trends. A complete description of ADS is available in a system design and user's manual[1].

This paper has the following objectives. First, North American monitoring networks currently participating in ADS are identified and the geographical coverage of sites is shown. Second, an overview of ADS is given. The underlying structure of the system is described, especially as it impacts potential uses of wet deposition data. Third, examples of standard statistical summaries available from ADS are given. Fourth, isopleth maps for pH, annual deposition of hydrogen, sulfate, nitrate and ammonium ion species for the period July 1980 to June 1981 are used to illustrate spatial analyses utilizing ADS. Spatial analysis is based on a statistical surface estimation procedure called kriging with the resulting surface then contoured. Each section is structured by an overview of the approach with specific examples and details to illustrate key points.

## Participating Monitoring Networks

The Acid Deposition System (ADS) is designed to integrate wet deposition data from multiple precipitation chemistry monitoring networks as suggested by a working group within the acid rain characterization community[2]. As a centralized source for wet deposition data, ADS facilitates access to North American data for the study of long-term spatial and temporal patterns. To accomplish this ADS has implemented procedures to indicate clearly the collocation of sampling instruments and to identify all samples collected at the same physical location even when different networks are involved. ADS does this while maintaining the integrity and identification of individual contributing networks.

Initially, emphasis in ADS has been directed at integrating data from existing routine, long-term networks. Several reports describe wet deposition networks and the data generated by them[3-6]. Not all of the networks described in these reports have submitted their data to be included in ADS. This paper includes data from NADP (National Atmospheric Deposition Program), CANSAP (Canadian Network for Sampling Precipitation), MAP3S/PCN (the MAP3S Precipitation Chemistry Network), APN (the Canadian Air and Precipitation Monitoring

Network), and EPRI-SURE (EPRI Sulfate Regional Experiment precipitation chemistry monitoring program). Other networks and organizations, including APIOS, UAPSP, and EPA regional offices, have submitted data for inclusion in ADS. Table I summarizes the characteristics of the networks. Further details are found in reports from the individual networks[7-16]. Figure 1 shows the sites currently in ADS.

The networks currently participating in ADS are continuing to provide data from their programs. A network's new data is added to ADS as soon as it is made available. Quarterly updates of data are expected. Other networks are being included in ADS. They are being added as quickly as the data transfer process can be implemented. Data from other acid deposition networks having a good Quality Assurance program are invited.

## Overview of ADS Structure

Important aspects of the philosophy of ADS is the integration of networks into a common data base and the identification of protocol changes at a single sampling site. Both of these concepts are central to a study of spatial and temporal variability and trends of wet deposition in North America. The ADS identification of a monitoring site is arbitrarily assigned but is specific to a geographical location. If multiple collectors, whether operated by the same network or not, are at the same location, they are identified by the same numerical ADS number but different letter, e.g., ADS site 53 in Raleigh, North Carolina, where 53a and 53b are operated by NADP and 53c and 53d are collocated samplers from the EPRI-SURE network. This facilitates intercomparison studies.

For each collector at a site, provision is made to identify changes in protocol through the use of site revision numbers. When a network makes a change in field, analysis or network operation that may affect the comparability of results over time, then ADS records a revision. All samples collected during a period between revisions are identified with a single revision number.

The ADS data base uses three main files: the SITE-SUMMARY file, the SAMPLE-DEFINITION file, and the COMPONENT-ANALYZED file.

There are several records per geographic location in the SITE-SUMMARY file. Each defines sampling conditions for a given time period at that location. The record with the highest revision number contains current information. The SITE-HISTORY file (discussed below) contains supporting narrative information. Information available includes network name, network site name, SAROAD code, FIPS code, site elevation latitude and longitude, protocol sampling period, collection instrument and analytical procedures and laboratories.

Table I. Description of monitoring networks currently in ADS.

| Network | Geographical Area | Period of Operation and Number of Sites | Number of Sites in 1981 | Sampling Period | Parameters Measured |
|---|---|---|---|---|---|
| National Atmospheric Deposition Program (NADP) | National Coverage of United States | Began in 1978 with 22 sites. Operation continuing for increased number of sites. | 81 | Weekly samples collected each Tuesday. | pH, conductivity, $SO_4^{=}$, $NO_3^-$, $NH_4^+$, $Cl^-$, $PO_4^{\equiv}$, $K^+$, $Na^+$, $CA^{++}$, $Mg^{++}$. |
| Canadian Network for Sampling Precipitation (CANSAP) | National Coverage of Canada | Began in 1977 with 45 sites. Operation continuing. | 54 | Monthly samples collected on last day of month. | pH, conductivity, $SO_4^{=}$, $NO_3^-$, $NH_4^+$, $Cl^-$, $K^+$, $Na^+$, $Ca^{++}$, $Mg^{++}$ |
| Canadian Air and Precipitation Monitoring Network (APN) | Eastern Canada | Began in November 1978 with 5 sites. Operation continuing. | 95 | Daily samples. | pH, $SO_4^{=}$, $NO_3^-$, $NH_4^+$, $Cl^-$, $K^+$, $Na^+$, $Ca^{++}$, $Mg^{++}$, total phosphorus |
| Acidic Precipitation in Ontario Study (APIOS) Cumulative Network | Ontario Province | Began in September 1980. Operation continuing. | 36 | Monthly samples. | pH, $SO_4^{=}$, $NO_3^-$, $NH_4^+$, $Cl^-$, $K^+$, $Na^+$, $Ca^{++}$, $Mg^{++}$, total Kjeldahl nitrogen, total phosphorus and trace metals: Zn, Fe, Ni, Cu, Pb, Al, Cd, Mn and V. |
| Acidic Precipitation in Ontario Study (APIOS) Daily Network | Ontario Province | Began in September 1980. Operation continuing. | 16 | Daily samples. | pH, conductivity, $SO_4^{=}$, $NO_3^-$, $NH_4^+$, $Cl^-$, $Na^+$, $Ca^{++}$, $Mg^{++}$, acidity. |
| MAP3S Precipitation Chemistry Network (MAP3S/PCN) | Eastern United States | Began operation in 1976 with 5 sites. Operation continuing | 9 | Event samples. | pH, conductivity, $SO_4^{=}$, $NO_3^-$, $NH_4^+$, $Cl^-$, $K^+$, $Na^+$, $Ca^{++}$, $Mg^{++}$, $PO_4^{\equiv}$, $NO_2^-$, $SO_3^{=}$ |
| EPRI Sulfate Regional Experiment Network EPRI/SURE | Eastern United States | Operated from October 1978 to September 1981. Nine sites in 1979 and 1980. | 5 | Event samples. | pH, conductivity, $SO_4^{=}$, $NO_3^-$, $NH_4^+$, $Cl^-$, $K^+$, $Na^+$, $Ca^{++}$, $Mg^{++}$, $PO_4^{\equiv}$, $Al^{+++}$, strong acids, total acids, total organic carbon |
| Utility Acid Precipitation Study Program (UAPSP) | Eastern and Central United States | Began operation in October 1981. | 19 | Daily samples. | pH, conductivity, $SO_4^{=}$, $NO_3^-$, $NH_4^+$, $Cl^-$, $K^+$, $Na^+$, $Ca^{++}$, $Mg^{++}$, $PO_4^{\equiv}$, strong acids, total acids |

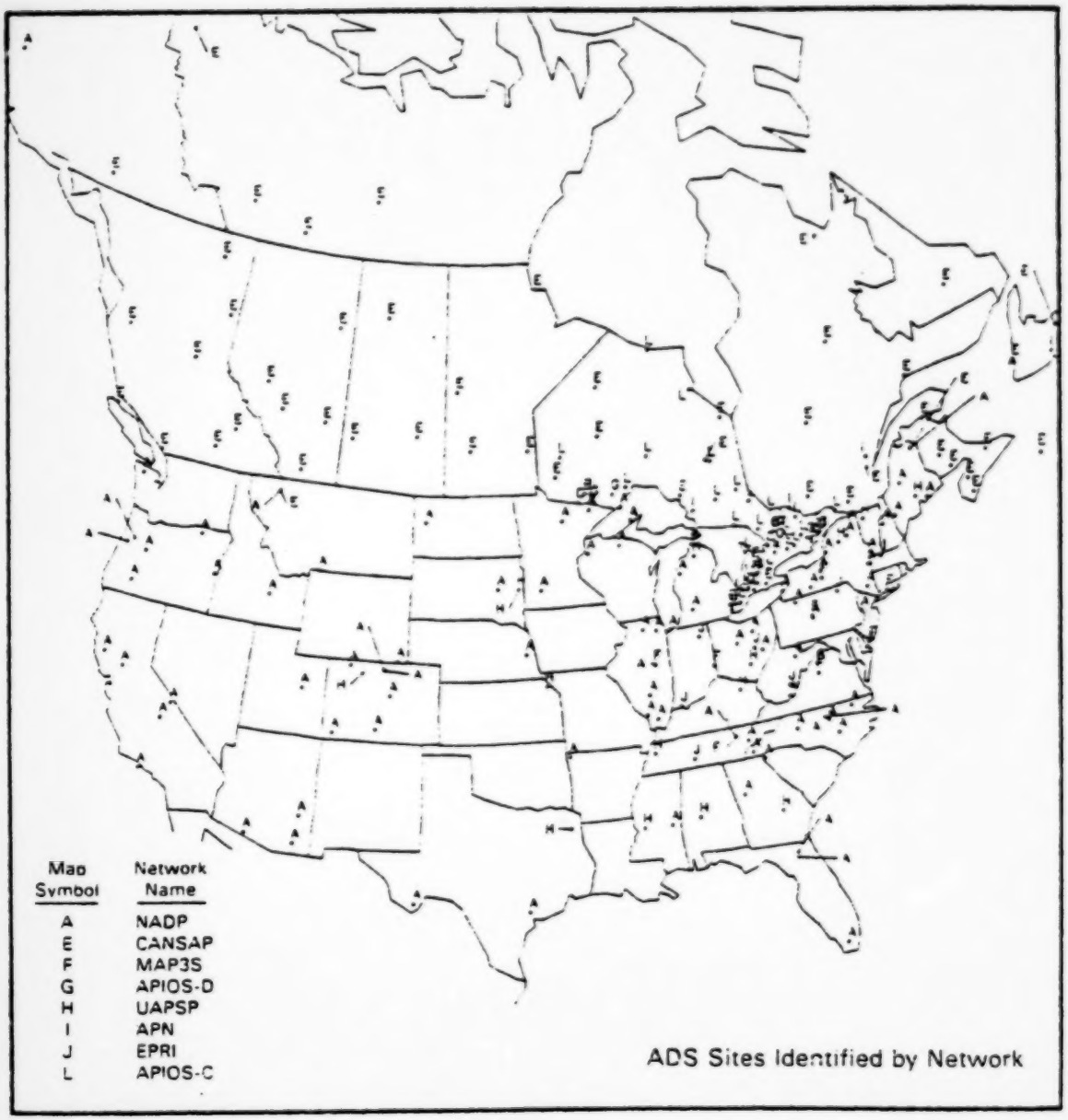


FIGURE 1. Geographic location and network identification of sites defined in ADS.

There is one record per sample (e.g. month, week, or event) in the SAMPLE-DEFINITION file. The sample definitions are tied to the site summaries by the unique ADS-IDENT number. The special case of quality control samples will be handled by a code in this file. Information available includes dates for sample start, sample end and laboratory arrival, precipitation occurrence and type, deposition type, whether sample met network protocol, standard precipitation depth, sample volume with associated error and coded comments associated with the sample.

There is one record per component analyzed per sample in the COMPONENT-ANALYZED file which is tied to the SAMPLE-DEFINITION file through the ADS-IDENT number, the ADS reference date, and the codes for the component (chemical species). This record contains the actual concentration measured for a particular chemical species as well as analysis date, comments specific to component and associated error values.

Not all networks provide all information ADS is capable of handling. Networks are encouraged to do so as the information is considered to be an integral part of documenting sample results.

There are two important ancillary files which contain relatively static information.

The SITE-HISTORY file contains information about the changes in the sampling protocol at each site. There are multiple records per geographic location in this file, one for each time there was a change in operating protocol at a site.

The NETWORK-ANALYSIS-PROTOCOL file contains information about the number and type of measurements normally performed on a sample, the instrument and technique used to measure the components, and a network supplied estimate of the accuracy of the measurements. There is one record per component measured at this site in this file.

There are several other minor files in the data base. One contains the expanded site definitions including mailing addresses, technical contact person, etc. Another contains a brief history of each network. A series of files are used as tables for code validation and translation.

## Statistical Summaries

For each site a standard statistical summary for the measurements made on the wet deposition sample is available. The number of sample periods with precipitation is reported along with the total precipitation as measured by the standard precipitation recording instruments at a site. In those cases where the standard precipitation amount is missing but a sample volume from the deposition collector is available, the latter is converted to a depth and used.

An example of the statistical summaries available is given in Table II for sulfate. The summaries are based on concentration measurements for samples collected according to the sampling period for a network: event, daily, weekly, or monthly. The sampling period must be considered in the interpretation of the data at a site. Comparisons across sites from different networks must be made with caution, especially if the sampling periods differ.

Ion species concentrations at a site are summarized with the concentration arithmetic mean and standard deviation and also the geometric mean and standard deviation. The geometric calculations are completed by taking the natural logarithms of the data, calculating the arithmetic mean and standard deviation of the logarithms and then exponentiating the results to give the geometric mean. The minimum and maximum concentrations as well as the percentile points (10, 25, 50, 75 and 90 percent) of the concentration frequency distribution are presented. The 50 percentile corresponds to the median of the ion species concentration at the site for the period, July 1980 through June 1981.

Each ion species precipitation-weighted concentration is also computed. The precipitation-weighted concentration is defined as the sum of the products (each precipitation depth times the species concentration in the sample) divided by the sum of the precipitation depths. Precipitation depths are from the standard precipitation gage collocated with the wet deposition collector. The sample volume, when available, is converted to a depth and used in the calculation whenever the standard precipitation depth is missing. For the ions generally considered to be conservative when samples are mixed together (sulfate, nitrate, ammonium, chloride, calcium, magnesium, sodium and potassium), the precipitation-weighted mean concentration is conceptually the same as the single value that would be measured if all samples had been poured into one container and analyzed. Annual wet deposition of an ion species is obtained by multiplying the annual precipitation depth by the annual precipitation-weighted mean ion concentration.

An annual statistical summary for a site is meaningful only if the sample data adequately characterize the precipitation chemistry actually occurring during the year at the site. Valid samples for all sampling periods during a year are typically not available for a site. The extent of samples missing is related to the ability to compute meaningful statistical summaries. The problem is addressed by specifying screening criteria for individual samples and for data completeness and representativeness at a site. No screening criteria for wet deposition sample data are currently universally agreed upon as appropriate. Efforts are being made to define "standard" screening criteria. The screening criteria applied to obtain the results in this paper should be viewed as preliminary and subject to change depending on the outcome of current efforts.

Screening criteria apply to individual samples and to sites. For individual samples, wet deposition samples only are included. All components, i.e., ion species, determined to be "suspect" or "unreliable" by a network are excluded. Individual samples are also excluded if the catch efficiency, i.e., ratio of

## TABLE II. Example of ion species annual statistical summaries for individual sites.

SULFATE (concentration: mg/l deposition: g/sq-m ) for period: Jul. 1980 - June 1981 04 DEC 83 Page 36

| State / Network / ADS ID / Site Name | Precip Weighting Vol N | Vol (ml) | Wtd Conc | Wtd Dep | Concentration Summary: Arithmetic N | Mean | SD | Geometric Mean | SD | Concentration Percentile Deciles: 0.10 0.50 1.0 10.0 50. |
|---|---|---|---|---|---|---|---|---|---|---|
| North Carolina NADP (Weekly) | | | | | | | | | | |
| 053a Finley (A) | 49 | 666 | 2.4 | 1.6 | 42 | 3.5 | 3.6 | 2.7 | 0.7 | |
| 169a Research Triangle | 36 | 603 | 2.3 | 1.6 | 36 | 3.4 | 3.0 | 2.7 | 0.7 | |
| 174a Research Triangle | 24 | 369 $ | | | 22 | | | | | |
| EPRI/SURE (Daily) | | | | | | | | | | |
| 053c Raleigh | 77 | 660 | 2.2 | 1.4 | 60 | 2.7 | 2.3 | 2.2 | 0.7 | |
| North Dakota | | | | | | | | | | |
| NADP (Weekly) | | | | | | | | | | |
| 062a Teddy Roosevelt N | 6 | 116 $ | | | 6 | | | | | |
| Ohio | | | | | | | | | | |
| NADP (Weekly) | | | | | | | | | | |
| 055a Delaware | 50 | 1145 | 3.6 | 4.4 | 43 | 3.6 | 1.2 | 3.3 | 0.4 | |
| 056a Caldwell | 49 | 1090 | 4.4 | 4.7 | 48 | 4.3 | 2.7 | 4.2 | 0.5 | |
| 058a Wooster | 47 | 962 | 3.6 | 3.4 | 44 | 4.1 | 2.1 | 3.6 | 0.5 | |
| MAP3s/PCN (Event) | | | | | | | | | | |
| 057a Oxford | 89 | 879 | 3.3 | 3.0 | 57 | 3.8 | 2.0 | 3.2 | 0.6 | |
| EPRI/SURE (Daily) | | | | | | | | | | |
| 153a Zanesville | 111 | 1487 | 3.3 | 4.9 | 98 | 3.7 | 2.0 | 3.1 | 0.6 | |
| Oregon | | | | | | | | | | |
| NADP (Weekly) | | | | | | | | | | |
| 027a Vines Hill | 33 | 266 @ | | | 17 | | | | | |
| 059a Alsea | 43 | 1297 | 0.5 | 0.6 | 37 | 0.9 | 1.0 | 0.6 | 0.8 | |
| 060a Schmidt Farm | 44 | 879 | 0.4 | 0.3 | 40 | 0.8 | 0.8 | 0.6 | 0.8 | |
| 061a H.J. Andrews | 38 | 1801 | 0.3 | 0.6 | 34 | 0.7 | 1.0 | 0.4 | 1.0 | |
| 170a Lost Creek | 24 | 593 $ | | | 21 | | | | | |
| 175a Pendleton | 27 | 291 @ | | | 19 | | | | | |
| Pennsylvania | | | | | | | | | | |
| NADP (Weekly) | | | | | | | | | | |
| 043a Tyler | 47 | 1139 @ | | | 32 | | | | | |
| 044a Leading Ridge | 49 | 935 | 3.6 | 3.3 | 47 | 4.6 | 3.3 | 3.6 | 0.7 | |
| MAP3s/PCN (Event) | | | | | | | | | | |
| 069a Penn State | 85 | 902 | 3.3 | 3.0 | 73 | 5.0 | 4.7 | 3.5 | 1.0 | |
| EPRI/SURE (Daily) | | | | | | | | | | |
| 151a Scranton | 43 | 301 $ | | | 42 | | | | | |
| South Carolina | | | | | | | | | | |
| NADP (Weekly) | | | | | | | | | | |
| 066a Clemson | 47 | 804 | 2.4 | 1.9 | 37 | 3.1 | 1.8 | 2.6 | 0.6 | |
| South Dakota | | | | | | | | | | |
| NADP (Weekly) | | | | | | | | | | |
| 067a Huron | 22 | 325 @ | | | 15 | | | | | |

0.10 0.50 1.0 10.0 50.

Note: $ = concentrations not calculated; SURE did not meet screening criteria
@ = concentrations not calculated; less than 75% of annual precipitation analyzed for this component
. = warning: at least one measurement was reported as less than detection limit.

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predicted depth using sample volume to standard precipitation collector depth, is less than 0.5 or greater than 2. Note that the last criteria is not applied to CANSAP sites. Missing concentrations are excluded naturally. The samples remaining after the above screening criteria are considered valid samples and are used in statistical summaries.

Statistical summaries for major precipitation chemistry measurements are only given for sites meeting specific screening criteria. Each site is required to be in operation for at least nine months during the period July 1980 - June 1981. This screens sites that either started operation or ended operation during the report period. For CANSAP at least nine monthly sample values (75%) must be valid before annual concentrations and depositions are given in the report. Two other screening criteria are applied to other networks. First, an overall annual catch efficiency (CE) criteria of $0.5 \leq CE \leq 2.0$ is required. Catch efficiency is defined as the ratio of the sum of the predicted depths from sample volume to the sum of the standard gage precipitation depth. A site with extremely low or high catch efficiency is indicative of lost samples, sampler malfunctions or poor field collection. Failure on this screening criteria results in no annual summaries for any precipitation chemistry measurement for the site. A second criteria is applied to individual ion species at a site. An annual report for concentration and deposition of an ion species is given if the total predicted depth for the valid ion species samples is at least 75% of the total standard gage precipitation depth at the site.

Other standard statistical summaries are available. One or more ion species concentration or deposition at a site are summarized as three month running averages over a specified time period. Individual sample characteristics including ion species concentration are available in printed form when only a seasonably short time period and number of sites are requested. Larger subsets of sample data in ADS are available on magnetic tape. New statistical summaries and reports are being developed to meet user requirements.

## Spatial Patterns

The number of sites measuring wet deposition has increased rapidly from 1975 to 1981. This is the result of an increase in networks interested in long-term regional monitoring and also an increase in sites for existing networks. These additional sites enhance the ability to study spatial patterns in the United States and Canada. In this section a set of figures are presented to illustrate the type of contour maps planned to present deposition spatial patterns. The contour maps are based on wet deposition data from the NADP and CANSAP networks.

Estimating the spatial distribution of an ion species annual average concentration or annual deposition is a problem of estimating a spatial surface and then displaying the estimated surface by constructing contour lines. Surface estimation is essentially a problem of interpolation between measurement sites. A number of techniques provide a solution to the problem.

The contour maps presented here use an interpolation technique called kriging to estimate the surface. The surface is then contoured by computer with the final contour lines presented being smoothed by hand. Finkelstein and Seilkop[17] studied the application of kriging techniques to acid precipitation data. They used observations from the NADP network for 1979 and concluded that kriging offered some distinct benefits for the spatial analyses of acid precipitation data. Kriging explicitly incorporates spatial correlation that exists across sites[18-20].

Figure 2 shows the spatial pattern for pH. Lowest pH values occur in the north central United States where annual average pH is slightly less than 4.2 pH units. Most of the eastern United States and southeastern Canada have pH levels below 4.6. Western North America has pH levels generally between 5.0 and 6.0. The density of monitoring sites is substantially less in the western portion which limits estimation of reliable contour lines. Dashed lines denote contour line segments with substantial uncertainty in their location.

Figure 3 shows the spatial pattern for hydrogen ion deposition. The values are annual precipitation-weighted hydrogen ion depositions derived from pH measurements. Hydrogen ion deposition exceeds 60 milli eq/$m^2$ over Ohio, West Virginia, and western Pennsylvania. The same pattern exists as for pH. A comparison of the contours for pH and $H^+$ clearly illustrates the subjectivity involved in which contour levels are selected and how even smoothed contour lines tend to have more detail than the estimation process warrants.

Figures 4, 5 and 6 show annual deposition for sulfate, nitrate and ammonium ions. The deposition patterns are similar to the corresponding concentration patterns. The north central states and southeastern Canada exceed an annual deposition of 3 g/$m^2$ for sulfate. Nitrate and ammonium depositions exceed 2 g/$m^2$ and 0.4 g/$m^2$, respectively, in southern Ontario and Ohio with much of Indiana and Michigan included for ammonium as well.

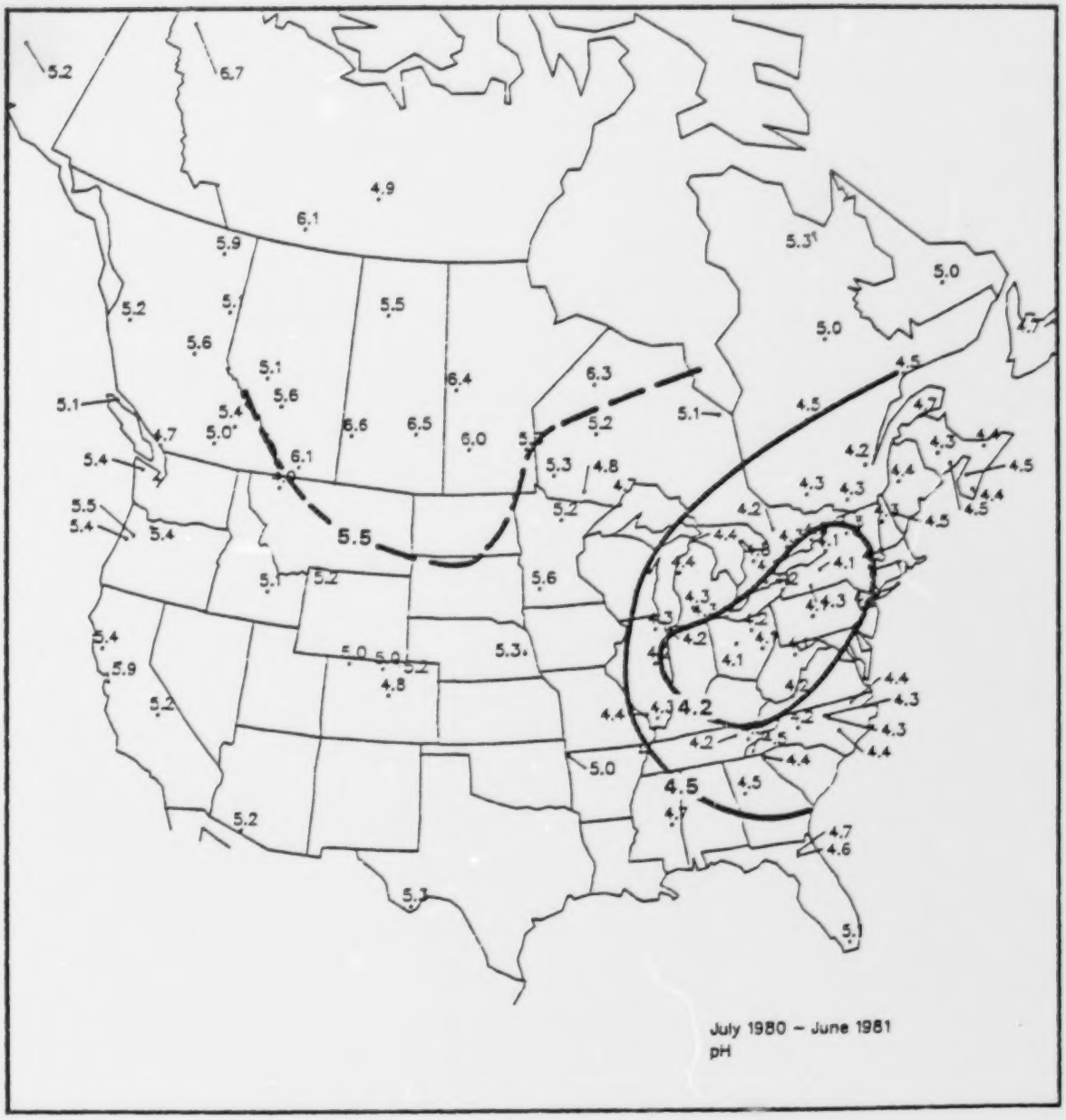


FIGURE 2. Spatial pattern of precipitation-weighted average pH for period July 1980 - June 1981 using data from NADP and CANSAP.

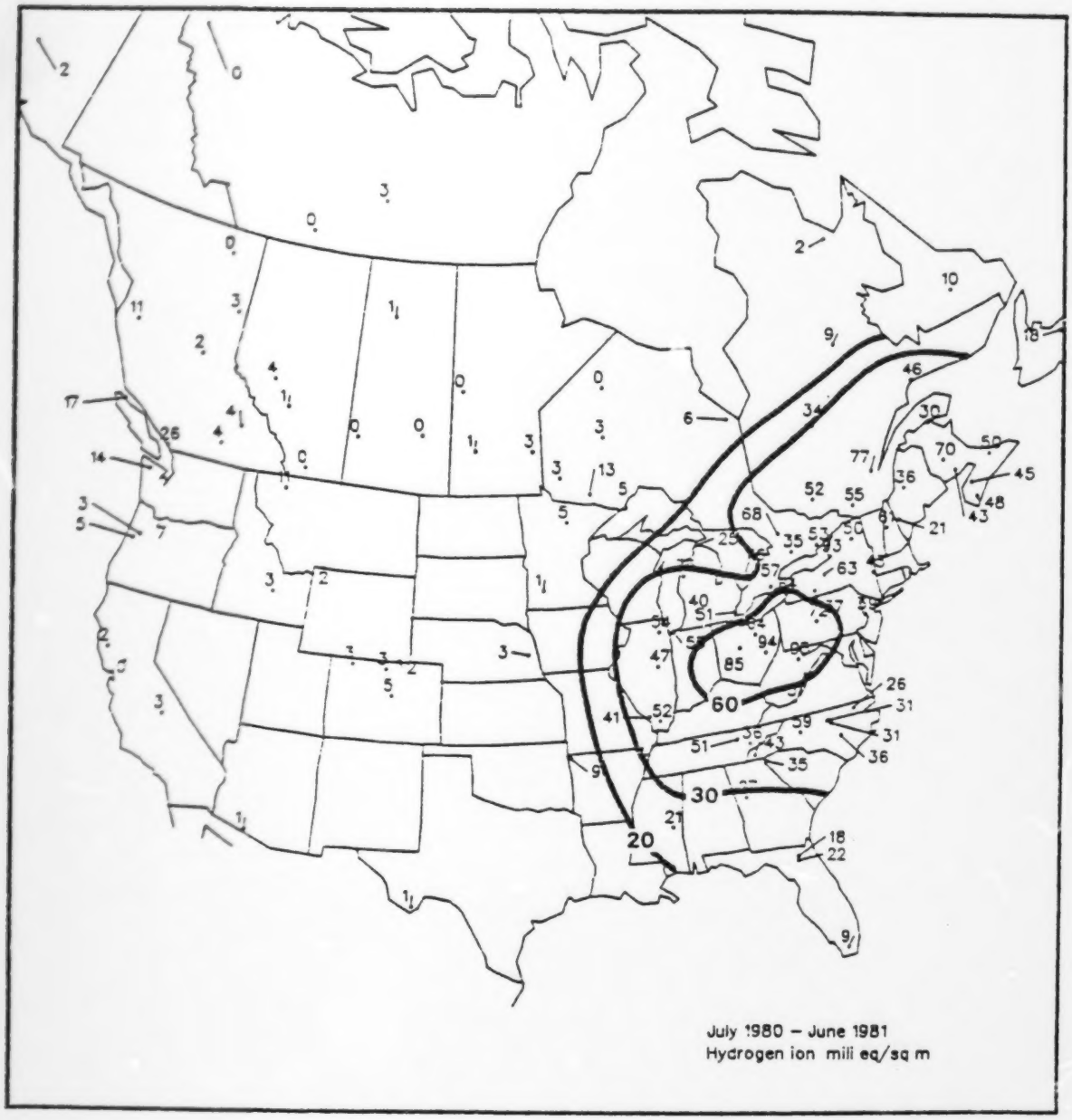


FIGURE 3. Spatial pattern of hydrogen ion wet deposition (milli eq/$m^2$) for period July 1980 -- June 1981 using data from NADP and CANSAP.

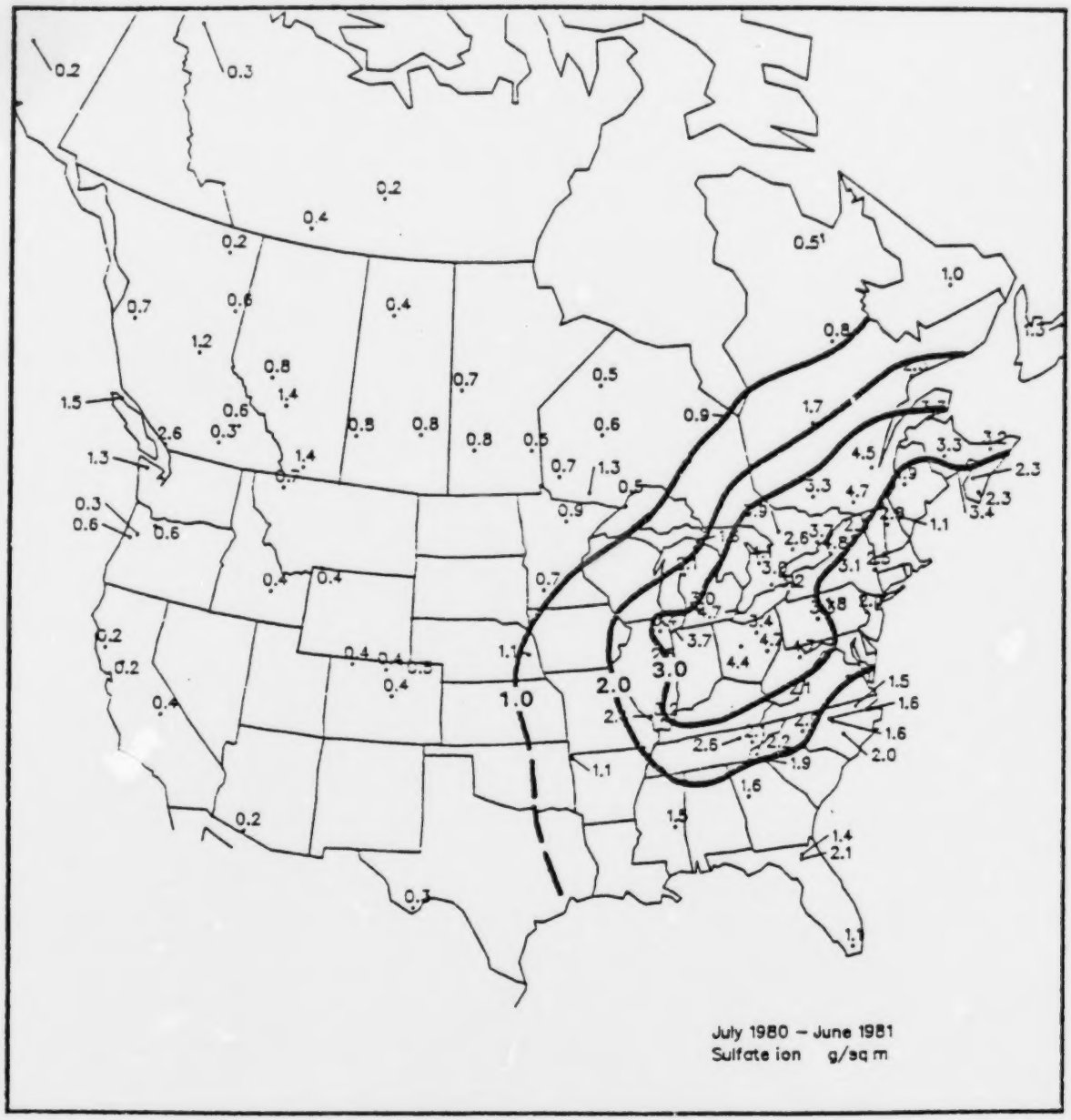


FIGURE 4. Spatial pattern of sulfate ion wet deposition ($g/m^2$) for period July 1980 - June 1981 using data from NADP and CANSAP.

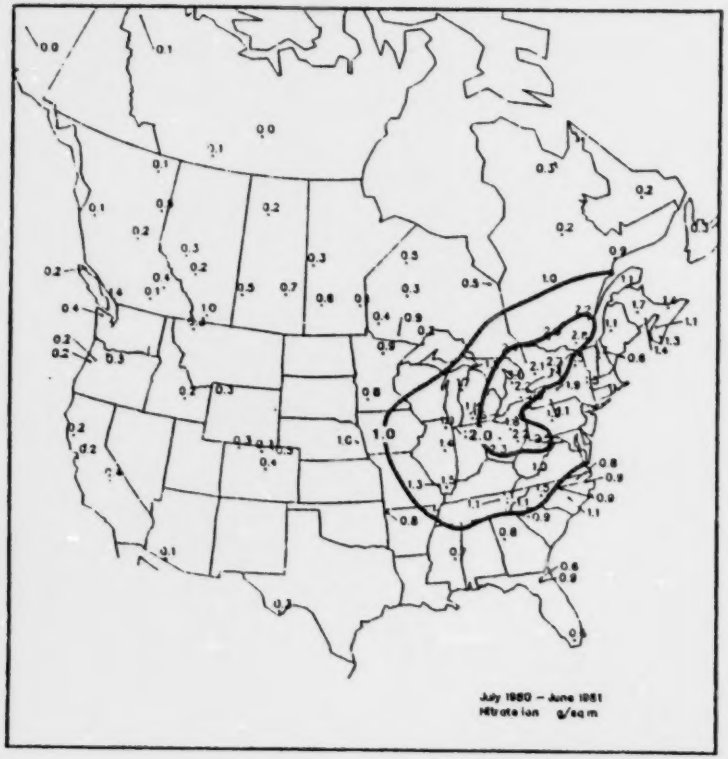


FIGURE 5. Spatial pattern of nitrate ion wet deposition ($g/m^2$) for period July 1980 - June 1981 using data from NADP and CANSAP.

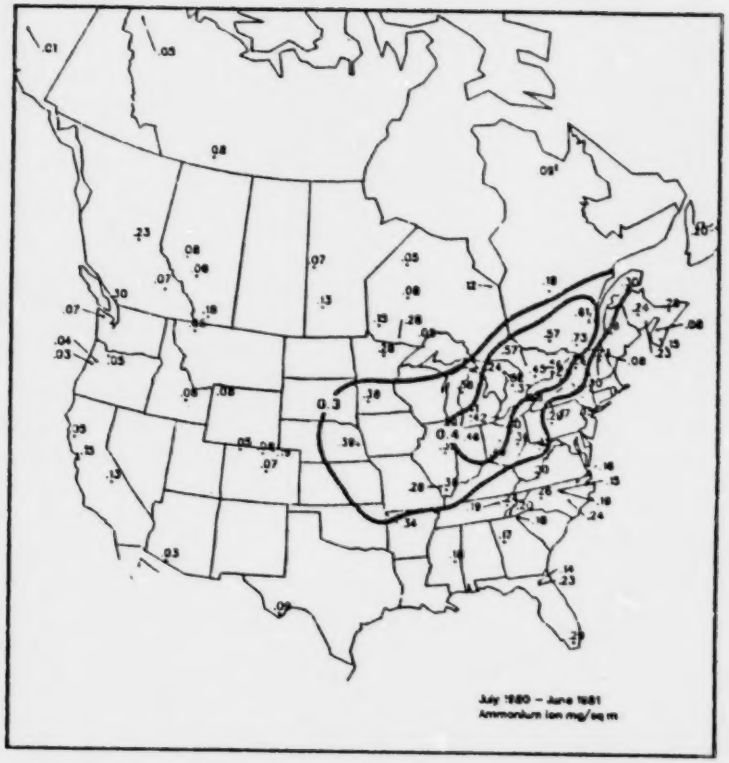


FIGURE 6. Spatial pattern of ammonium ion wet deposition ($g/m^2$) for period July 1980 - June 1981 using data from NADP and CANSAP.

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